TECHNICAL INFORMATION

TECHNOLOGY

Y-Junction circulator

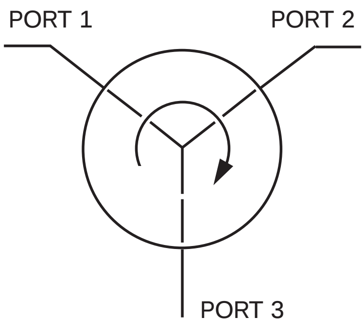


FIG. 1

The Y-junction circulator uses spinel ferrites or garnet ferrites in the presence of a magnetic bias field, to provide a non-reciprocal effect. A 3-port circulator (shown in figure 1) is the basic model which can be used to explain how it operates.

If a signal is applied at port # 1, it will emerge from port # 2 with a loss characteristic called insertion loss. Typical values of insertion loss 0.1 to 0.5 dB.

In the reverse direction, there will be leakage at port # 3 from the incoming signal at port # 1. This leakage called isolation is typically 20 dB below incoming power at port # 1.

Due to the “3rd order symmetry” of the Y-junction the behavior is the same for the other ports, with respect to port # 1 to port # 2; port # 2 to port # 3 and port # 3 to port # 1. The circulator's role is to pass energy, for instance, in the RF-head of a radar, assuring high isolation between the high power transmitter and the sensitive low power receiver (figure 2).

The Y-junction exists in three main technologies:

- Coaxial devices: these feature triplate technology with coaxial connectors.
- Drop-in circulators: in triplate or microstrip technology.
- Waveguide devices: These consist of three waveguides forming an H-plane junction in either a "T" or a "Y"-symmetrical structure.

When very high power is needed, the technology uses a four-port differential phase shift duplexer.

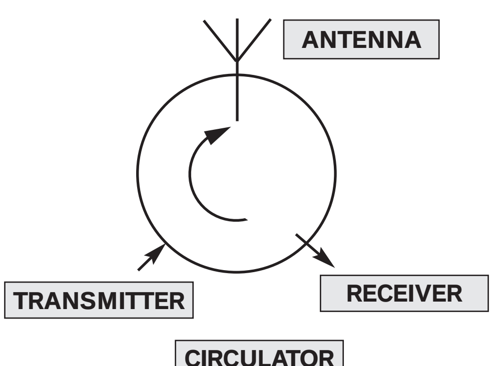


FIG. 2

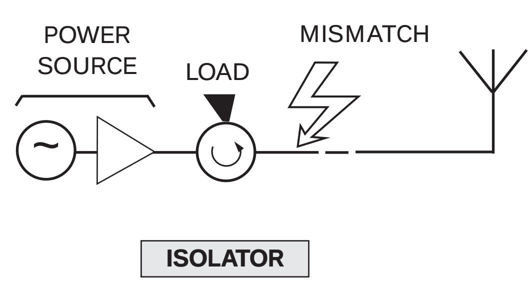


FIG. 3

A Y-junction circulator can be made into an isolator by adding an internal termination on port # 3, for example.

The device passes signals with low loss (port # 1 to port # 2) and with high loss in the opposite direction.

It is used to "isolate" one microwave device from another. It can, for example, protect expensive, high-power RF sources from variations in loading conditions or mismatching (see figure 3).

4-Port differential phase shift circulator

This four-port-device is normally used with one load, such as a high-power circulator (duplexer); or with two dummy loads, such as a high-power isolator.

This circulator consists of three basic parts:

- hybrid folded magic tee
- twin parallel ferrite phase shift sections
- 3 dB coupler

Resonance isolator - Waveguide devices

By magnetically biasing a ferrite inside a waveguide, the non-reciprocal effect is obtained: with low losses in one direction and high losses (isolation) in the opposite direction.

Those isolators are only used for low and medium power (see figure 4).

The ferrite material has to dissipate the return power due to mismatch.

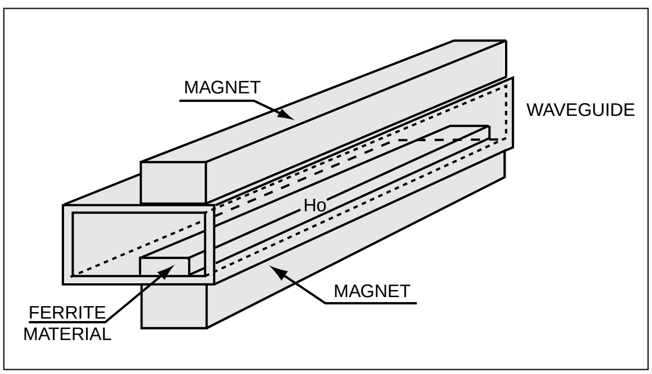


FIG .4

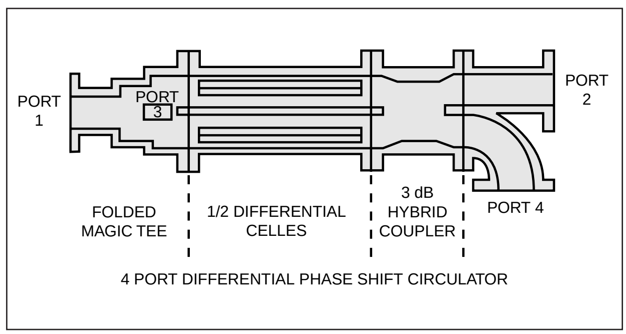


FIG. 5

Ferrite switches

These devices change the polarity of the magnetic bias (N → S) and the RF-signal direction of circulation. This is made by a coil instead of a magnet. This technology is used for ferrite switches in both product lines:

- Y-junction
- 4 port differential phase shift device

ELECTRICAL FEATURES

All the parameters - insertion loss, isolation, VSWR, power - given in this section are absolute maximum ratings assured in the operating temperature range. Typical values are obviously better.

Insertion loss (I.L.)

If a signal is applied at port # 1, it will emerge from port # 2 with a loss characteristic called insertion loss which will be the ratio of the output signal to the input signal expressed in dB:

$$I.L\ dB = 10 \log_{10} \left[\frac{P_{in}}{P_{out}} \right]$$

Typical values: 0.1 to 0.4 dB.

Isolation

- For an isolator:

  If a signal is applied at port # 2, it will emerge from port # 1 with a high insertion loss called isolation which is also expressed in dB. (ratio of the output signal to the input signal).

- For a circulator:

  It should be noted that in the case of a circulator this parameter is not applicable. But it is common to use this parameter as if the circulator could be made into an isolator by terminating one port (e.g. port # 3) with a matched load. The isolation measured is dependent on the VSWR of both the termination and the circulator port.

Typical values: -20 to -30 dB

VSWR

The reflection coefficient magnitude $|\rho|$ characterizes the reflective property of each port of an isolator or circulator (see Fig. 6).

$$|\rho| = \sqrt{\frac{P_{reff}}{P_{in}}}$$

It is useful to use the voltage standing wave ratio (VSWR)

$$VSWR = \frac{1 + |\rho|}{1 - |\rho|}$$

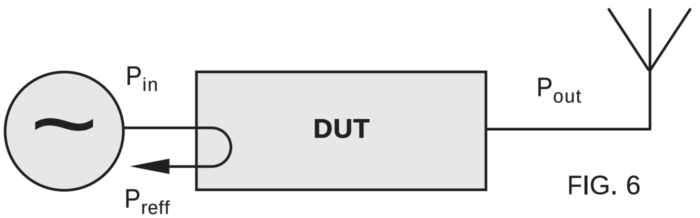


FIG. 6

Typical values: 1.07: 1 to 1.25: 1

Effect of an isolator on VSWR (see Fig.7)

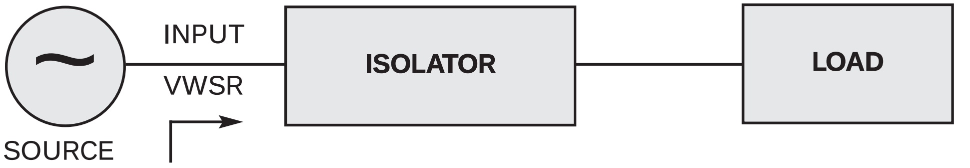


FIG. 7

The effective input VSWR of an isolator will vary at a function of the load VSWR. If the output load mismatch is increased, energy is reflected at the termination port, attenuated by the isolation and then reflected back to the input. This effect increases the total input VSWR observed at the input.

Example:

The load VSWR is 10: 1, the isolator has 18 dB isolation, which improves the input VSWR to 1.20: 1.

Temperature range

The performance of a circulator or isolator is limited by ferrite and magnet material behavior in the operating temperature range.

In this catalog, for each device the main specifications are given:

- at room temperature: 25°C
- over a specified temperature range.

Power rating

The input power to a ferrite device can be supplied from a CW or a pulsed source.
For pulsed source, peak and average power should be specified, pulse duration and duty cycle are also needed in order to determine an adequate safety margin.

Average Power

For high power products, average power is limited by the dissipation in the ferrite. Adequate cooling is necessary to insure the ferrite material does not reach excessive temperature.
There are three kinds of cooling: liquid, forced air, or natural convection.

Peak power

To avoid breakdown or arcing, special ferrite materials are designed.
Frequency of operation and peak-power level determine whether the waveguide circulator should be pressurized or unpressurized with dry air or gas (N_2 or SF_6).

Load VSWR

Power rating of a ferrite device depends upon the mismatch at the output port (load VSWR); for instance for an isolator if load VSWR is 2: 1, more than 10% of the input power is reflected inside the ferrite device to the internal load.

In case of short-circuit (infinite load VSWR) the ferrite device has to handle the equivalent of twice the input CW-power, and the equivalent of a peak power equal to 4 times the input power, based on the higher internal voltage levels.

Therefore, the time-duration of short circuit or high load VSWR, is needed in order to determine an adequate safety margin.

Third order intermodulation products (IMP_{32})

Harmonics and third order intermodulation products appear when non-linear elements are used such as ferrite materials, metal welds, surface finish...

When two tones - F_l and F_2 - are applied to a ferrite device, the relative amplitudes of $2F_l - F_2$ and $2F_2 - F_l$ are critical in some communication systems and should be specified when ordering (see Fig. 8).

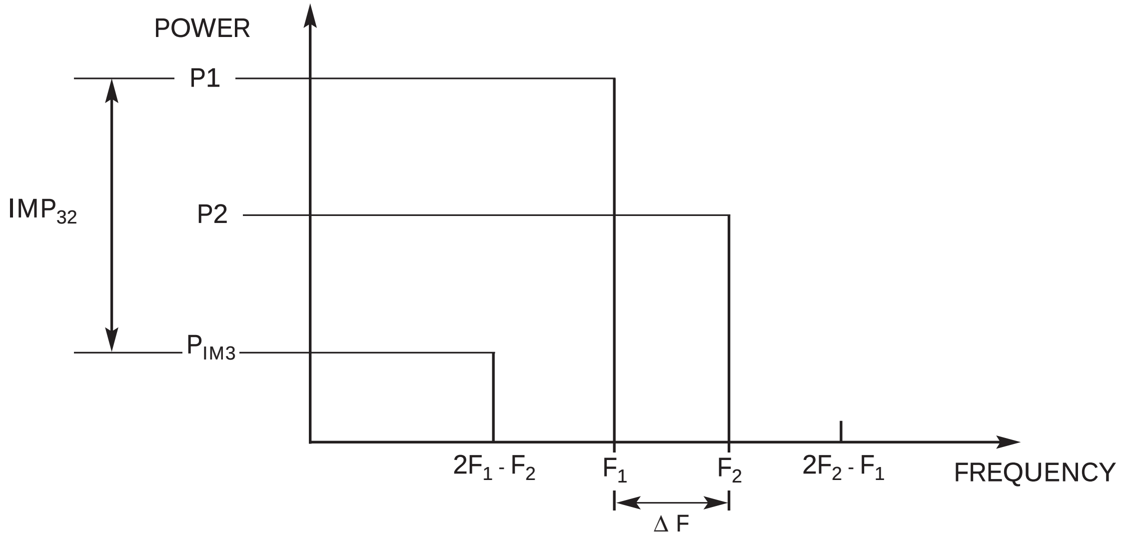


FIG. 8

- Test conditions (to be specified)
  - F_1 and F_2
  - P_1 and P_2 in W or dBm

- Third order intermodulation products
  - P_{IM3} in dBm or,
  - $IMP_{32} = P_{IM3} - P_1$ in dBc

MEASUREMENT OF THE MICROSTRIP DEVICES CARRIER TYPE (ISOLATORS/CIRCULATORS).

1. CONSTRUCTION REQUIREMENTS OF THE TEST FIXTURE.

1.1 For the tuning of the Ferrite Microstrip Devices uses the test fixture as it shown at the Fig 6.3. The connecting microstrip line (matching plate) is a 50 Ohm line. The material of this connecting microstrip line is Al_2O_3 (ε_r = 9-10)

1.2 In order to provide the reference, a 50 Ohm Calibration microstrip line is required. The material of the Calibration microstrip line is Al_2O_3 (ε_r = 9-10).

1.3 Thickness (and the width) of the carrier for the calibration line should be the same as thickness (and the width) of the Ferrite device's carrier (TH3=TH6, Fig 1 and Fig 2.).

1.4 Thickness of the substrate for the calibration line should be the same as thickness of the Ferrite device's thickness (t3=t6, Fig 1 and Fig 2.).

1.5 Thickness of the connecting microstrip line (matching plate) shouldn't be greater than 1.3× thickness of the ferrite device ($t3 \le t2 \le 1.3 \times t3$, Fig 2).

1.6 Thickness of the connecting microstrip line (matching plate) shouldn't be greater than 1.3× thickness of the Calibration microstrip line ($t6 \le t2 \le 1.3 \times t6$, Fig 1).

1.7 The gap between the carrier of the Calibration microstrip line and the test fixture (Z3, Fig1) should be as small as possible (less than 2 micrometers).

1.8 The gap between the carrier of the Ferrite device and the test fixture (Z3, Fig2) should be as small as possible (less than 2 micrometers).

1.9 Width of the connecting microstrip line (matching plate) shouldn't be greater than 1.3× Width of the Calibration microstrip line ($W6 \le W2 \le 1.3 \times W6$, Fig 1).

1.10 It is very important to provide the following equation for the connecting microstrip line (matching plate): $D \ge 5 \times W2$ (Fig 1 and Fig 2)

1.11 VSWR of the each adapter should be less then 1.15:1. We recommend using the Microstrip Distributed Load as described at the Fig 3.

1.12 The Microstrip Distributed Load should have the same thickness as the thickness of the microstrip device ($h_l = t_3$, Fig 1 and Fig 3) for the measurement of the adapters VSWR.

1.13 VSWR of test fixtures should be less then 1.30:1

2. RECOMMENDED CALIBRATION METHOD FOR THE TEST FIXTURE.

2.1 Proceed with the calibration of the test equipment without the test fixture.

2.2 FIG. 1. Place the calibration microstrip line (50 Ohm microstrip line) into the test fixture. The carrier of the calibration microstrip line should have the same overall dimensions as the ferrite device's carrier (width and thickness). The gap between the connecting microstrip line and the calibration microstrip line should be less than 35 micron (Z1, Fig1). Coplanarity of the upper surface of the connecting microstrip line and the calibration microstrip line should be controlled (Z2 less then 30microns, Fig1).

2.3 Connect the connecting microstrip lines and calibration microstrip line with tabs (as described below and in Fig1). Connection tabs width should be greater than 75% and should not exceed 100% of the W2, W6 (Fig1). Tabs should be pressed to the microstrip line along the length of the tab (this is usually performed with a wooden toothpick). We recommend Ag_3 In (Silver Indium) solder material (solder material foil thickness t4=20-30 micrometers, Fig1 and Fig 2) for the tabs. Tabs should not extend outside the microstrip line.

2.4 Connect the test fixture to the Network Analyzer.

2.5 It is very important to first check the VSWR of the test fixture since the VSWR of the test fixture can cause an error in the measurement of Insertion Loss. VSWR of the test fixture should be less than 1.30:1 to provide correct measurement of the insertion loss.

2.6 If everything is OK you will see 1.0 to 1.3 dB loss. Keep a record of this Insertion Loss.

2.7 FIG. 2 Replace the Calibration microstrip line with the isolator. Gap between the connecting microstrip line and the Isolators input (output) microstrip line should be less then 35 micrometers (Z1, Fig2). Coplanarity of the upper surface of the connecting microstrip line and the isolator should be controlled (Z2 less then 30 microns, Fig2).

2.8 We do not recommend using glue or soldering for the mounting the isolator in the test fixture. We suggest using a fiberglass plate to press the circuit into place.

2.9 Connect connecting microstrip lines and isolator's input (output) lines with the tabs. (Fig2). Connection tabs width should be greater than 75% and should not exceed 100% of the W2, W3 (fig2). Tabs should be pressed to the microstrip line along the length. We recommend Ag_3In solder material (Silver-Indium solder material foil thickness t4=20-30 micrometers, Fig1, 2) for the tabs. Tabs should not extend outside the microstrip line.

2.10 The following is the method for determining the correct Insertion Loss data :

I.L. = Measurement data – Memory data (from 2.6 above)+ K.

"K" is a factor used in determining loss per unit length.

$K = 0.00143 \times L6 \times (Freq)^{-2}/W6$;

L6, W6 –in millimeters, Freq – in GHz

$K \approx 0.1$ to 0.17 dB

2.11 You can estimate the error of the Insertion loss measurement as:

$\delta A = 20 \times Log(1-G_1 \times G_2 - G_3 \times G_2 - S^2 \times G_1 \times G_3)$

$G_i = (VSWR_i - 1)/(VSWR_i + 1)$

$VSWR_1$ – Generator VSWR;

$VSWR_2$ – Test fixture VSWR

$VSWR_3$ – Load VSWR;

A (measurement loss, dB) = $20 \times log(1/S)$

MEASUREMENT OF THE SUBSTRATE TYPE MICROSTRIP DEVICES (ISOLATORS/CIRCULATORS).

3. CONSTRUCTION REQUIREMENTS OF THE TEST FIXTURE.

3.1 For the tuning of the Ferrite Microstrip Devices uses the test fixture as it shown at the Fig 6.3. The connecting microstrip line (matching plate) is a 50 Ohm line. The material of this connecting microstrip line is Al_2O_3 (ε_r = 9-10)

3.2 In order to provide the reference, a 50 Ohm Calibration microstrip line is required. The material of the Calibration microstrip line is Al_2O_3 (ε_r = 9-10).

3.3 Thickness of the connecting microstrip line (matching plate) shouldn't be greater than 1.3× thickness of the ferrite device ($t3 \leq t2 \leq 1.3 \times t3$, Fig 5).

3.4 Thickness of the connecting microstrip line (matching plate) shouldn't be greater than 1.3× thickness of the Calibration microstrip line ($t6 \leq t2 \leq 1.3 \times t6$, Fig 4).

3.5 Width of the connecting microstrip line (matching plate) shouldn't be greater than 1.3× Width of the Calibration microstrip line ($W6 \leq W2 \leq 1.3 \times W6$, Fig 4).

3.6 It is very important to provide the following equation for the connecting microstrip line (matching plate): $D \geq 5 \times W2$ (Fig 4 and Fig 5)

3.7 VSWR of the each adapter should be less then 1.15:1. We recommend using the Microstrip Distributed Load as described at the Fig 3.

3.8 The Microstrip Distributed Load should have the same thickness as the thickness of the microstrip device ($h_l = t_3$, Fig 1 and Fig 3) for the measurement of the adapters VSWR.

3.9 VSWR of test fixtures should be less then 1.30:1

3.10 The base section should be made of a material as described in the certificate of compliance for the device [magnetic (steel or kovar) or non-magnetic]

3.11 The surface of the base section should be smooth (surface roughness should not exceed 40 micrometers).

4. RECOMMENDED CALIBRATION METHOD FOR THE TEST FIXTURE.

4.1 Proceed with the calibration of the test equipment without the test fixture.

4.2 FIG. 4. Place the calibration microstrip line (50 Ohm microstrip line) into the test fixture. The calibration microstrip line should have the same overall dimensions as the ferrite device (width and thickness). The gap between the connecting microstrip line and the calibration microstrip line should be less than 35 micron (Z1, Fig 4). Coplanarity of the upper surface of the connecting microstrip line and the calibration microstrip line should be controlled (Z2 less then 30microns, Fig 4).

4.3 Connect the connecting microstrip lines and calibration microstrip line with tabs (as described below and in Fig 4). Connection tabs width should be greater than 75% and should not exceed 100% of the W2, W6 (Fig 4). Tabs should be pressed to the microstrip line along the length of the tab (this is usually performed with a wooden toothpick). We recommend Ag_3 In (Silver Indium) solder material (solder material foil thickness t4=20-30 micrometers, Fig 4 and Fig 5) for the tabs. Tabs should not extend outside the microstrip line.

4.4 Connect the test fixture to the Network Analyzer.

4.5 It is very important to first check the VSWR of the test fixture since the VSWR of the test fixture can cause an error in the measurement of Insertion Loss. VSWR of the test fixture should be less than 1.30:1 to provide correct measurement of the insertion loss.

4.6 If everything is OK you will see 1.0 to 1.3 dB loss. Keep a record of this Insertion Loss.

4.7 FIG. 5. Replace the Calibration microstrip line with the isolator. Gap between the connecting microstrip line and the Isolators input (output) microstrip line should be less then 35 micrometers (Z1, Fig5). Coplanarity of the upper surface of the connecting microstrip line and the isolator should be controlled (Z2 less then 30 microns, Fig5).

4.8 We do not recommend using glue or soldering for the mounting the isolator in the test fixture. We suggest using a fiberglass plate to press the circuit into place.

4.9 Connect connecting microstrip lines and isolator's input (output) lines with the tabs. (Fig 5). Connection tabs width should be greater than 75% and should not exceed 100% of the W2, W3 (Fig 5). Tabs should be pressed to the microstrip line along the length. We recommend Ag_3In solder material (Silver-Indium solder material foil thickness t4=20-30 micrometers, Fig 4 and Fig 5) for the tabs. Tabs should not extend outside the microstrip line.

4.10 The following is the method for determining the correct Insertion Loss data used

I.L. = Measurement data – Memory data (from 2.6 above)+ K.

"K" is a factor used in determining loss per unit length.

$K = 0.00143 \times L6 \times (Freq)^{-2}/W6;$

L6, W6 –in millimeters, Freq – in GHz

$K \approx 0.1$ to 0.17 dB

4.11 You can estimate the error of the Insertion loss measurement as:

$\delta A = 20 \times Log(1 - G_1 \times G_2 - G_3 \times G_2 - S^2 \times G_1 \times G_3)$

$G_i = (VSWR_i - 1)/(VSWR_i + 1)$

$VSWR_1$ – Generator VSWR

$VSWR_2$ – Test fixture VSWR

$VSWR_3$ – Load VSWR

A (measurement loss) = $20 \times log(1/S)$

ASSEMBLING OF THE MICROSTRIP FERRITE DEVICE IN THE CUSTOMER'S EQUIPMENT

5.1. The best performance of the Microstrip Devices can be achieved if the adjacent elements have VSWR less than 1.15.

5.2. For the adjacent elements with the poor VSWR, we would recommend to use the matching element (special microstrip line) between this element and Ferrite Device.

5.3. We do not recommend the direct connection from the coaxial center conductor to the Microstrip Ferrite Device due the mismatch (Fig 6.1, 6.2)

5.4. Our experiments shows that this type connection could cause a substantial decrease in performance of the ferrite devices, especially for the high frequency microstrip ferrite devices (Microstrip Isolators and Circulators whose operating frequency exceeds 24GHz).

5.5. We would recommend the examinations of the VSWR of the coaxial connectors and the transition from these connectors to the microstrip line.

5.6. To provide such testing recommends replacing the microstrip ferrite device with the microstrip distributed load (Fig 3.) and connect the microstrip distributed load directly to the coaxial connector. VSWR should be less than 1.15. If VSWR of this connection is higher there is a possibility that you will have 0.2dB to 0.5dB additional insertion Loss due the mismatching.

5.7. To correct the problem of poor mismatch between the coaxial connector and the ferrite microstrip device we would recommend to use a matching microstrip plate in order to obtain the best performance of the microstrip device.

5.8. Table 1. presents the experimental results of a 34.0 to 36.0Ghz microstrip Isolator, with two different connections to coaxial connectors.

	Microstrip Isolator	Fig 6.2	Fig. 6.3
Frequency Range, GHz	34-36	34-36	34-36
VSWR of the connector	-	1.30	1.15
Insertion Loss, dB	0.8	1.3-1.6	1.0-1.2
Isolation, dB	18	18	18
VSWR	1.30	1.50-1.60	1.40

5.9. Fig 7. describes the tuning process of the matching microstrip plate

5.9.1. Connect the matching microstrip line to the coaxial connector.

5.9.2. Connect the Microstrip distributed load as described in section 3.0 and 4.0

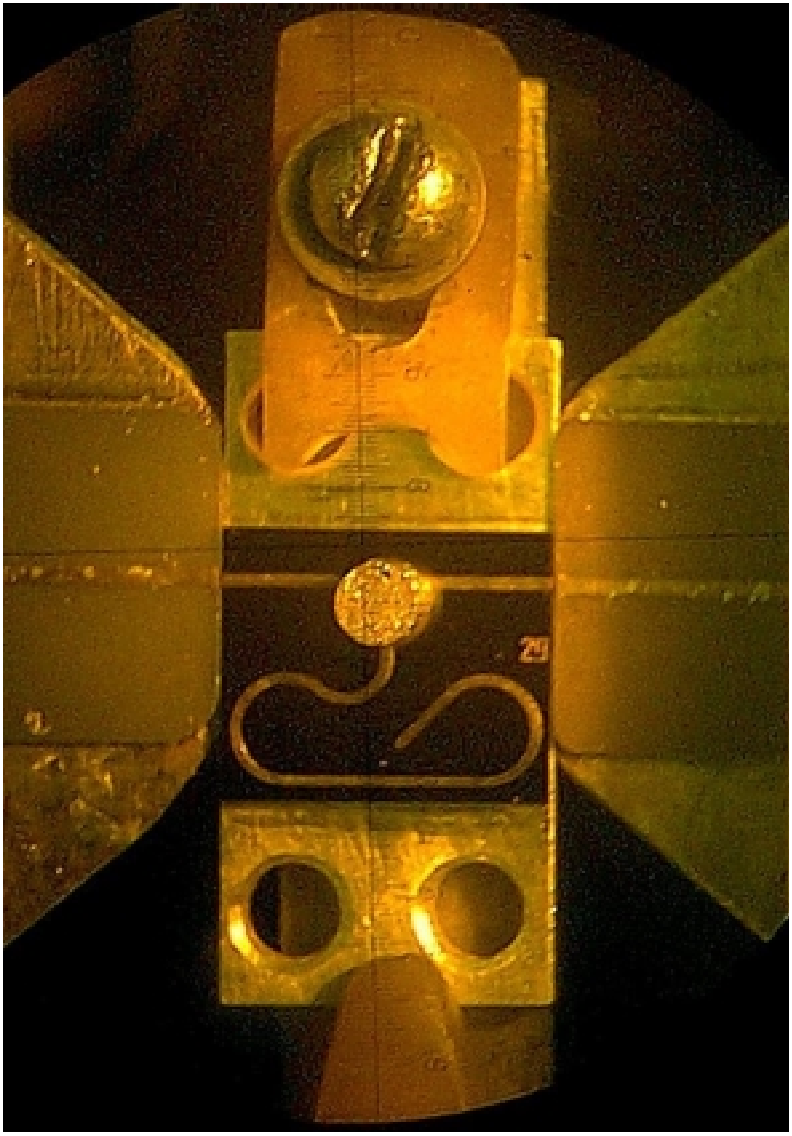
5.9.3. recommends the Ag_3In (silver Indium) solder material (foil, thickness 20-30micrometers) for the tuning of the matched microstrip plate. The dimensions of the tuning elements are ≈0.5×0.5 (0.75×0.75) mm.

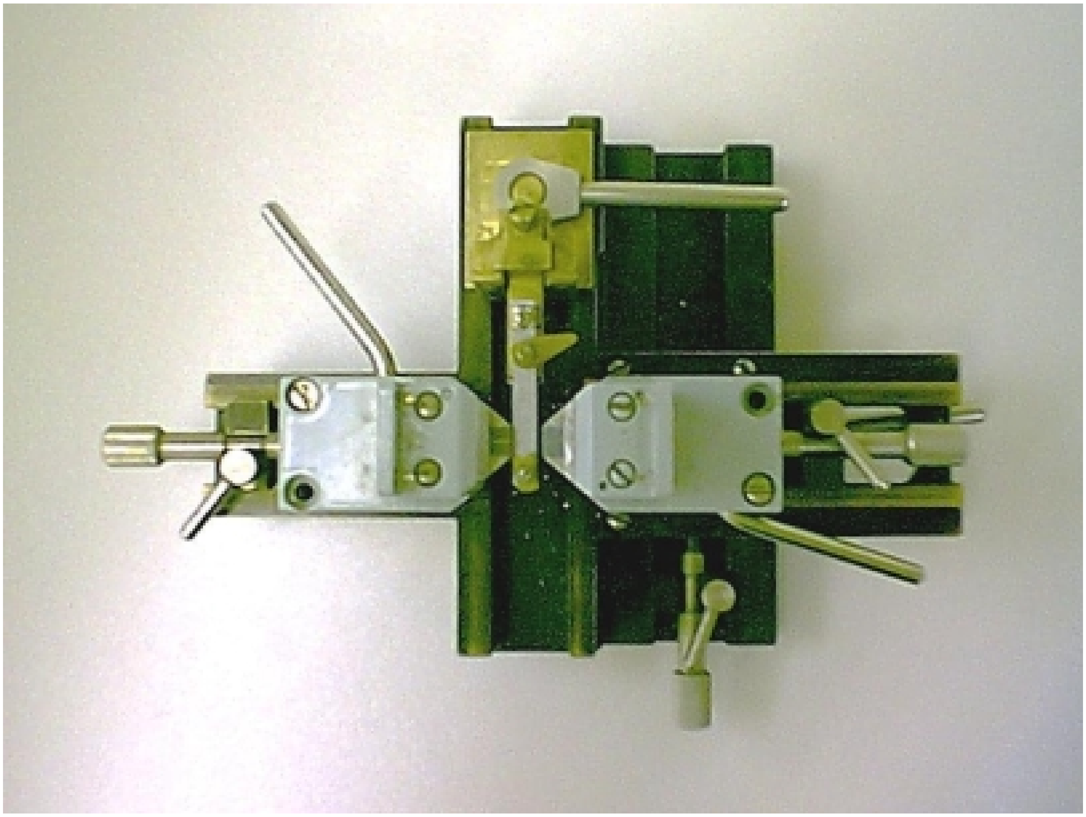
5.9.4. Move the tuning elements along the microstrip line to achieve the best VSWR. The tuning elements should then be tightly pressed to the microstrip line. (Fig 7.2)

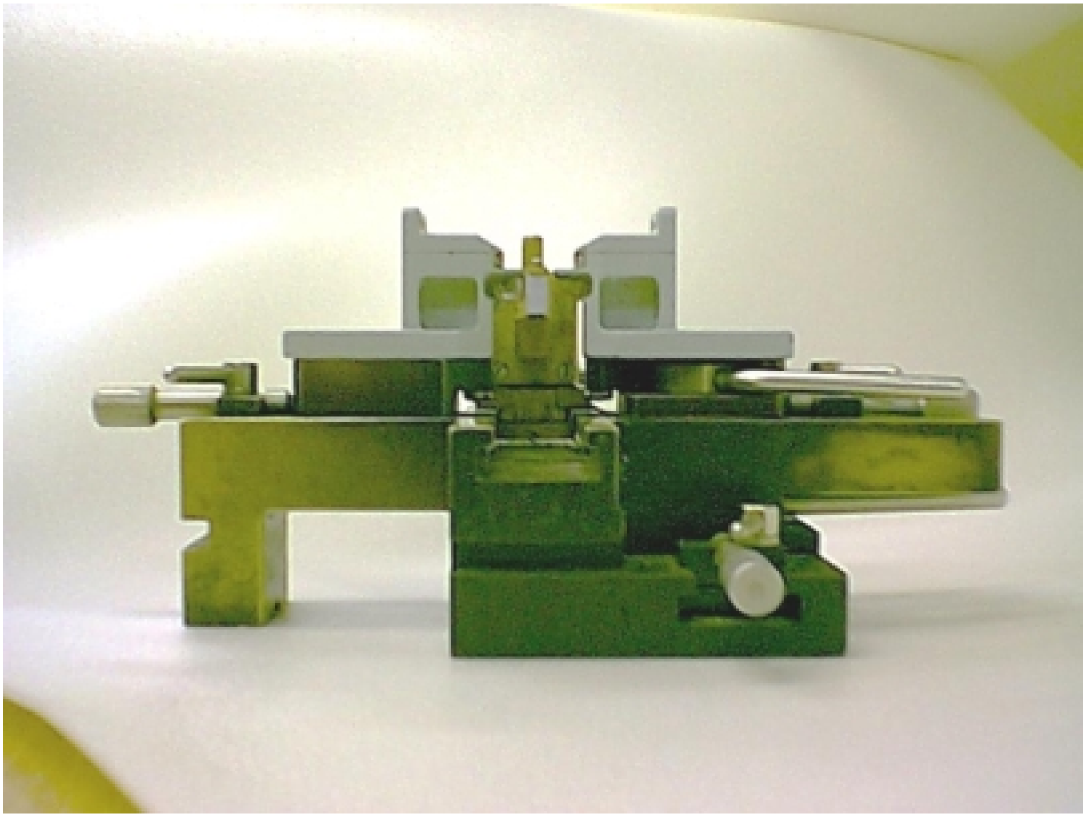
5.9.5. Fix the tuning elements with epoxy or lacquer

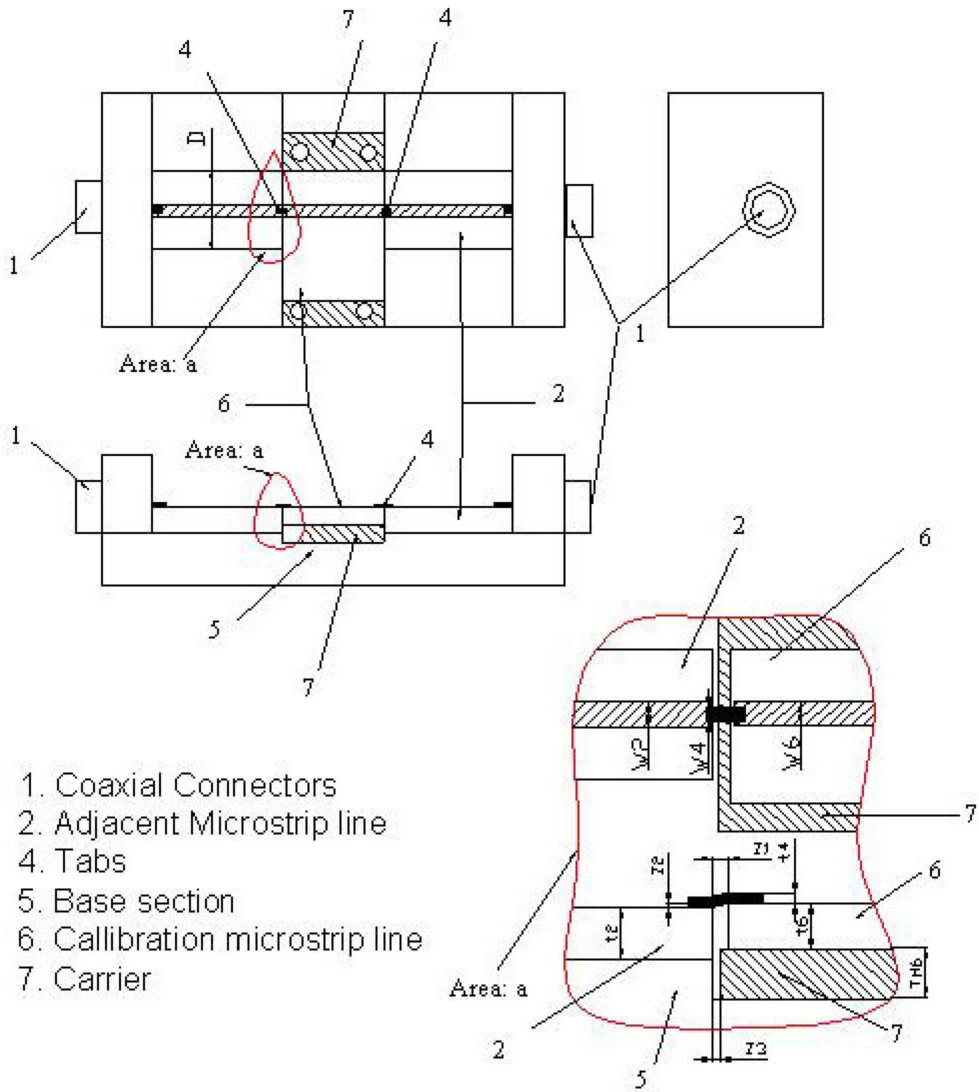
5.9.6. After few tests you will be able to understand the size and location of the tuning elements (See Fig 7.3) and include these element to the circuit of the matched microstrip line as shown in Fig7.3

TEST FIXTURE



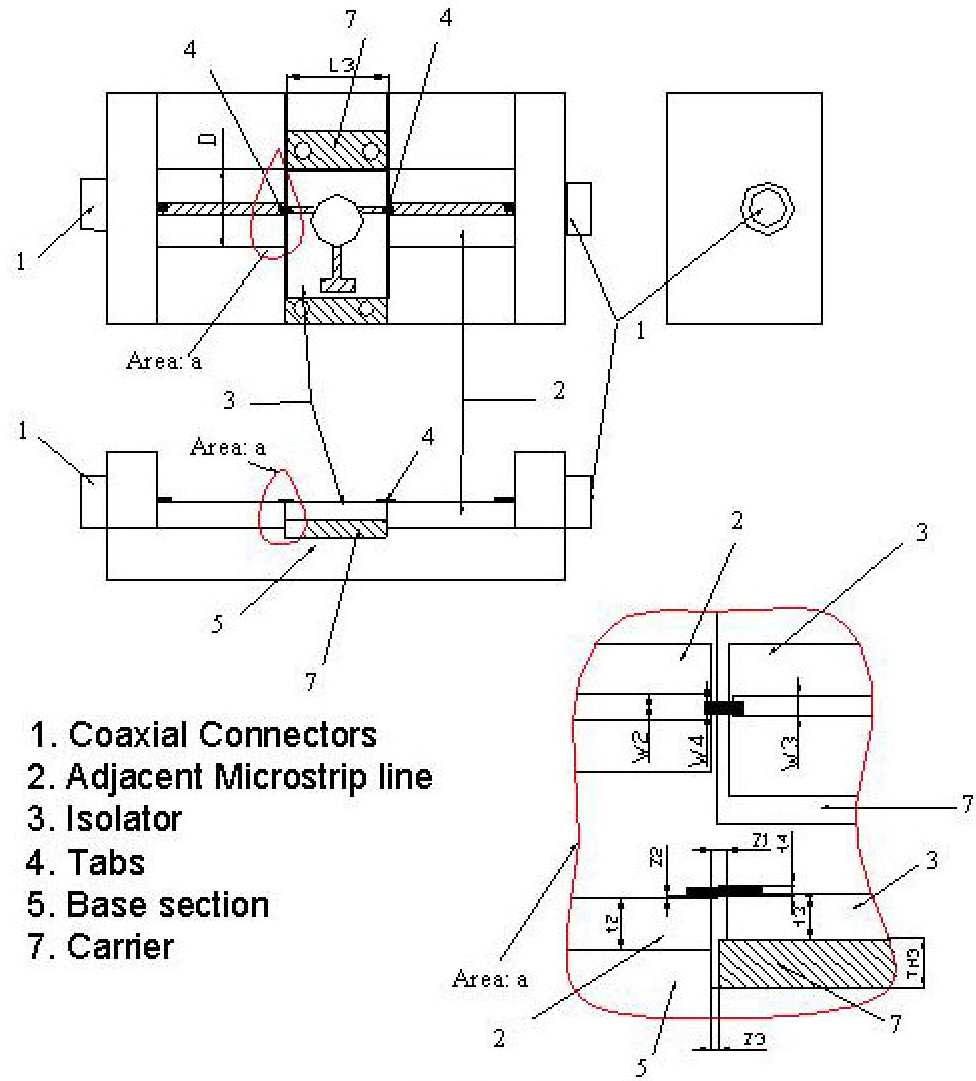






7
4
4
D
1
1
Area: a
6
2
1
Area: a
4
5
7
2
6
W2
W4
W6
7
T1
T4
T2
T6
6
T2
TH6
Area: a
2
7
5
T3
1. Coaxial Connectors
2. Adjacent Microstrip line
4. Tabs
5. Base section
6. Callibration microstrip line
7. Carrier

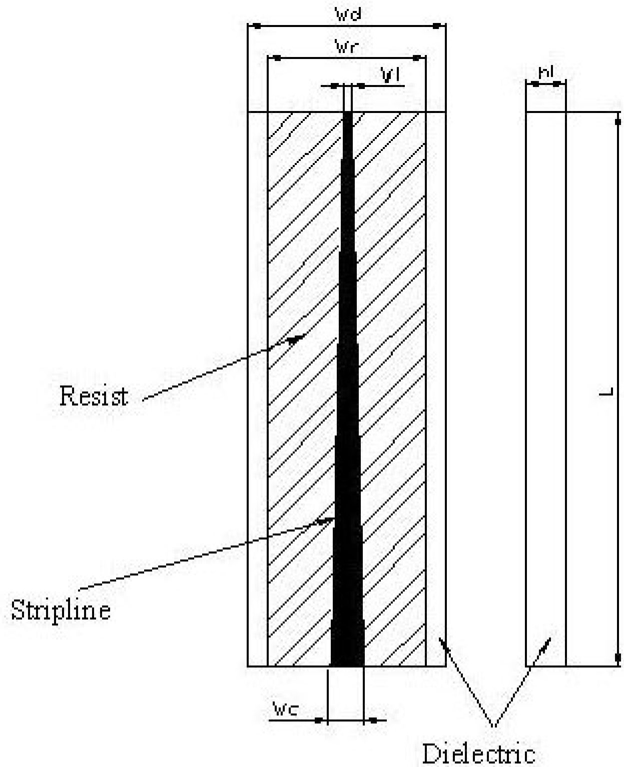
FIG. 1



L3
D
Area: a
W2
W4
W3
Z1
Z2
Z3
t1
t3
t4
TH3
1. Coaxial Connectors
2. Adjacent Microstrip line
3. Isolator
4. Tabs
5. Base section
7. Carrier

FIG. 2

Microstrip load for the measurement the adapters VSWR



Notes:

1. 1.4× Width of the adjacent microsrtip line $\geq$ Wl $\geq$ 1.2× Width of the adjacent microsrtip line
2. $Wr \geq 4 \times Wc$
3. $Wd \geq 5 \times Wc$
4. 1.4× thickness of the adjacent microsrtip line $\geq hl \geq$ thickness of the adjacent microsrtip line
5. $L \geq 5 \times$ wavelength in the dielectric
6. $VSWR_{load} \leq 1.12$

FIG. 3

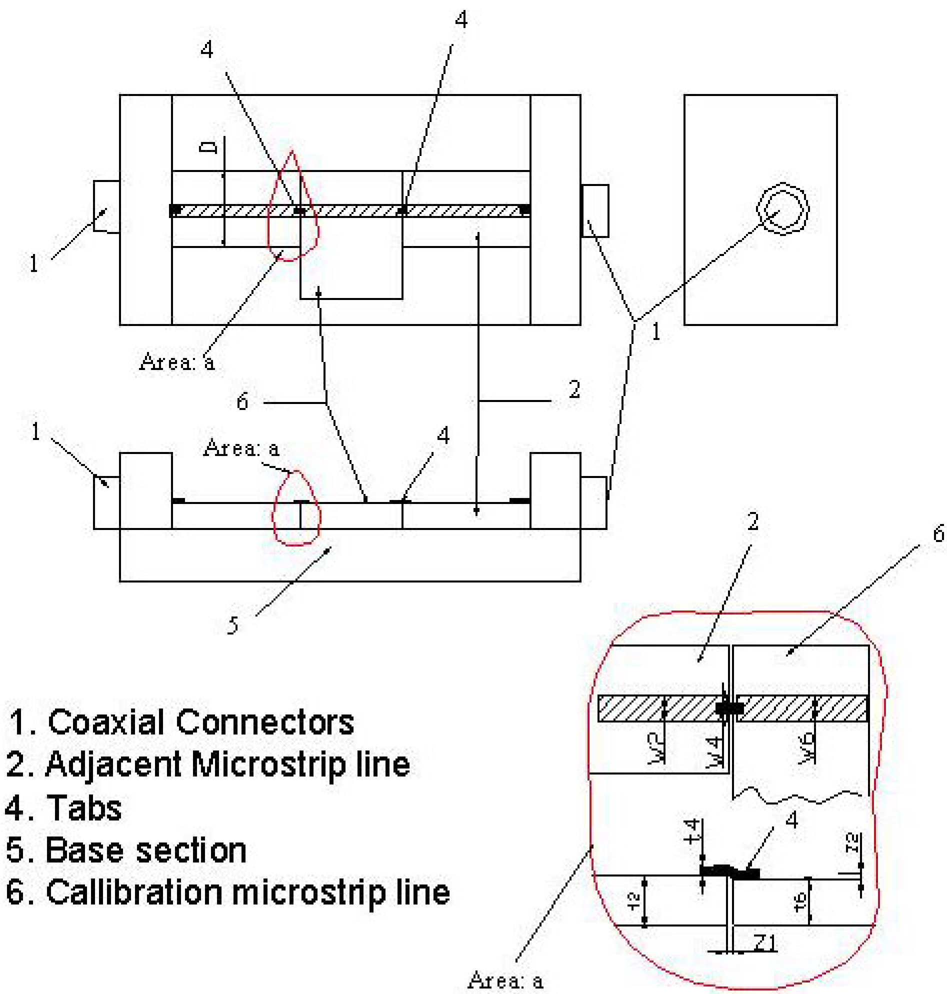

1. Coaxial Connectors
2. Adjacent Microstrip line
4. Tabs
5. Base section
6. Callibration microstrip line
Area: a
D
W2
W4
W6
t4
t2
t6
Z1
Z2

FIG. 4

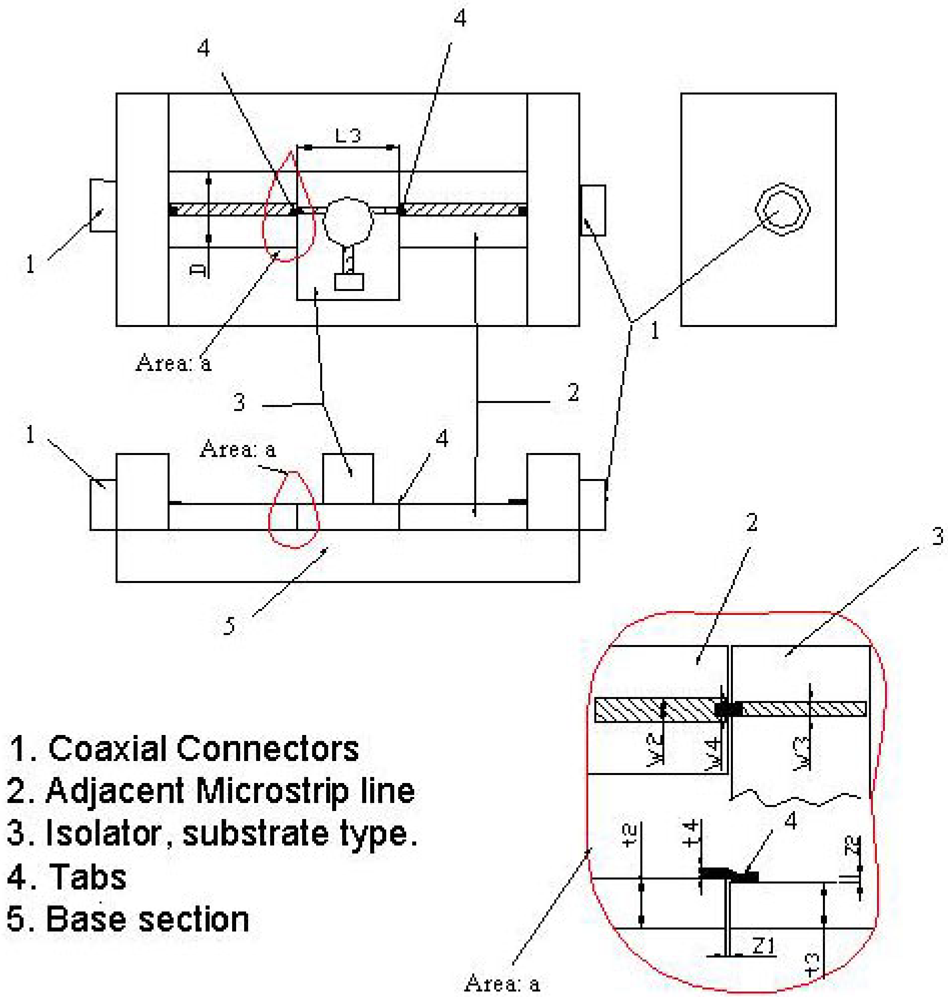

4
4
L3
1
D
Area: a
1
3
2
1
Area: a
4
5
2
3
W2
W4
W3
t2
t4
4
Z2
Z1
t3
Area: a
1. Coaxial Connectors
2. Adjacent Microstrip line
3. Isolator, substrate type.
4. Tabs
5. Base section

FIG. 5

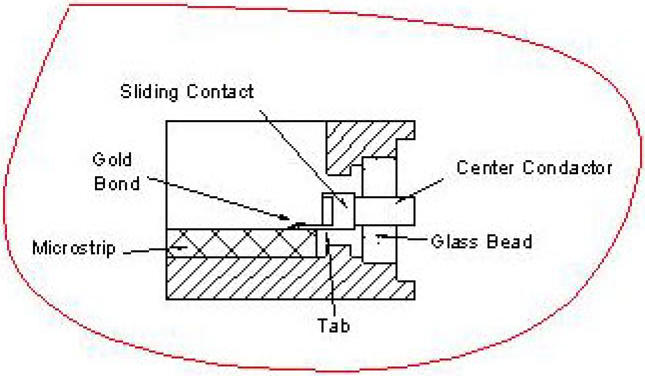


FIG. 6.1

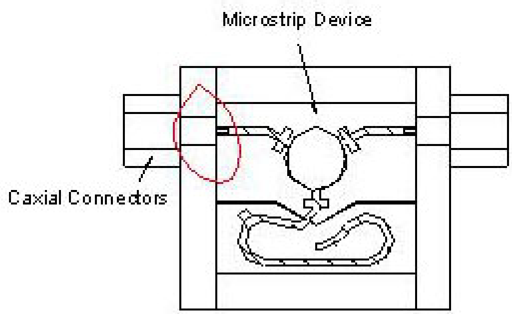


FIG. 6.2

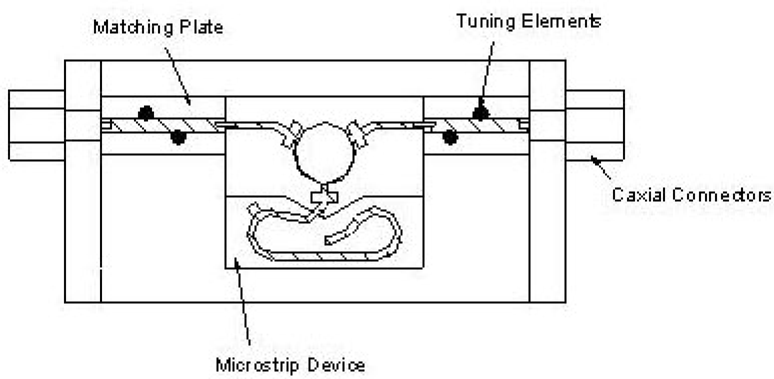


FIG. 6.3

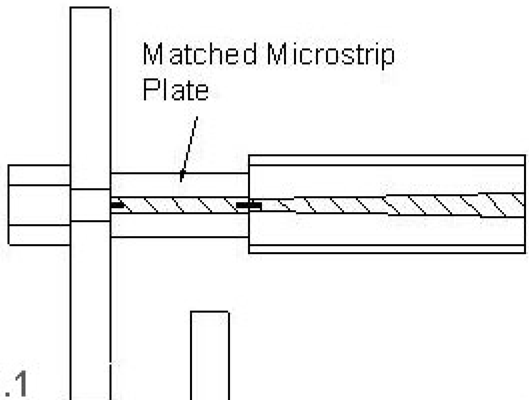


FIG. 7.1

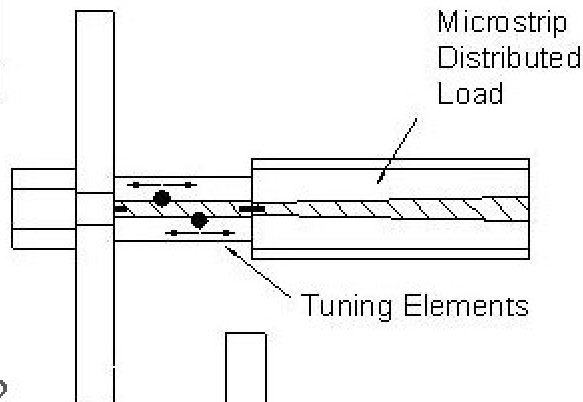


FIG. 7.2

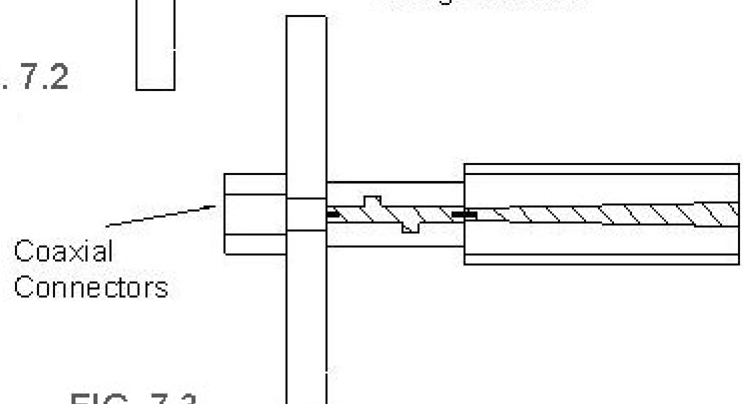


FIG. 7.3